Efficacy of Fluon Conditioning for Capturing Cerambycid Beetles in Different Trap Designs and Persistence on Panel Traps Over Time

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ABSTRACT Fluon PTFE is a fluoropolymer dispersion applied as a surface conditioner to cross-vane panel traps to enhance trap efficiency for cerambycid beetles. We describe the results of three experiments to further optimize cerambycid traps of different designs and to test the effect of Fluon over time. We tested Fluon with Lindgren funnel and panel traps fitted with either wet or dry collection cups on catches of cerambycid beetles and how the effect of Fluon on panel traps persisted. Fluon-treated funnel traps with wet collection cups captured ≈ 6× more beetles than the untreated funnel traps with wet collection cups. Untreated funnel traps with dry collection cups did not capture any beetles; however, Fluon-treated funnel traps with dry collection cups captured an average of four beetles per trap. Fluon-treated panel traps with wet collection cups captured ≈9× more beetles than untreated panel traps with wet collection cups. Fluon-treated panel traps with dry collection cups captured ≈11× more beetles than untreated panel traps with dry collection cups. The effect of Fluon on capturing cerambycid beetles did not decline after use in one or two field seasons. There was no significant difference in the number of beetles captured in freshly treated panel traps compared with traps that had been used for 1 or 2 yr. Fluon-treated traps captured nine species that were not captured in untreated traps. Conditioning both Lindgren funnel and panel traps with Fluon enhances the efficacy and sensitivity of traps deployed to detect exotic cerambycid species, or for monitoring threatened species at low population densities.

KEY WORDS wood-boring insect, Fluon, Cerambycidae, pheromone trap

Fluon PTFE (Northern Products, Inc., Woonsocket, RI) is a fluoropolymer dispersion that acts as a surface conditioner when applied to cross-vane panel traps, rendering them more slippery and enhancing their efficacy for capturing cerambycid beetles (Graham et al. 2010). Other surface treatments, such as Rain-X (SOPUS Products, Houston, TX) and aerosol lubricants have also been shown to increase trap captures (Czokajlo et al. 2003, de Groot and Nott 2003, Sweeney et al. 2004, Allison et al. 2011). However, panel traps treated with Fluon captured an average of >14× more beetles than untreated control traps or Rain-X treated traps (Graham et al. 2010). Fluon is now used as a surface conditioner in many studies involving cerambycid beetles (Barbour et al. 2011, Mitchell et al. 2011, Ray et al. 2011).

Previous research only tested the use of Fluon on cross-vane panel traps with dry collection cups (e.g., the collection cup of the trap is fitted with bottom screens to drain rain water, and no liquid killing agent is added to the collection cup). Lindgren funnel traps are also commonly used for capturing cerambycid beetles (Allison et al. 2001, 2003; Brockerhoff et al. 2006, Nehme et al. 2009). However, funnel traps are not as efficient as panel traps in capturing cerambycid beetles in large numbers (Dodds et al. 2010). It is not known how treatment with Fluon will affect the efficacy of funnel traps or panel traps fitted with wet collection cups (e.g., collection cups have a solid bottom and side drain screens to prevent overflow and are filled with a liquid killing agent such as propylene glycol, ethanol, soapy water, or saline solution).

The type of collection cup can have a significant effect on the retention rate of the trap. In previous studies, traps fitted with wet collection cups captured significantly more cerambycid beetles than traps fitted with dry collection cups (Morewood et al. 2002) even when an insecticide killing strip was added to the dry collection cups (Sweeney et al. 2006, Miller and Duerr 2008). The reduced retention rate of cerambycids captured in traps fitted with dry collection cups may be because of delayed mortality of beetles from insecticide exposure, allowing for a greater rate of escape from traps fitted with dry collection cups than traps fitted with wet collection cups in which beetles are immediately submerged (Morewood et al. 2002). Collection cups treated with Fluon increased the retention rate of cerambycid beetles (Graham et al. 2010), but the combination of Fluon treatment and wet collection cups was not tested. It is possible that the enhanced efficacy of wet collection cups versus

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dry collection cups completely or partially offsets the enhanced effect of Fluon treatment on trap surfaces for capturing cerambycids in traps with dry cups, which would make it unnecessary to treat traps fitted with wet collection cups with Fluon. However, beetles captured alive in traps fitted with dry collection cups can produce pheromones, which may enhance the attractive lures added to the traps and influence collection data (E.E.G., unpublished data).

Fluon treatments can drastically increase the number of cerambycid beetles captured; however, it is not known how long the slippery properties of Fluon will persist and continue to enhance insect capture on traps deployed in the field. When Fluon dries on the surface of a trap, it leaves a whitish, blotchy residue that can flake off through handling, exposure to extreme weather, or contact with trees and shrubs. Slow degradation of the Fluon could decrease the efficacy of the trap, and treatments may need to be reapplied annually. As of 2012, a single application of Fluon costs approximately \$4.50 per panel trap, based on current market prices. Knowing how long Fluon is effective as a surface conditioner will save time and money for regulatory agencies, forest managers, and scientists.

Here, we describe the results of three experiments that tested the efficacy of Fluon in capturing cerambycid beetles when applied as a surface conditioner on funnel and panel traps fitted with both wet and dry collection cups. We also describe the effect of Fluon on panel traps over time. Experiment 1 compared the number of cerambycid beetles captured in funnel traps with either wet or dry collection cups and conditioned with Fluon or left untreated. Experiment 2 compared the number of cerambycid beetles captured in panel traps with either wet or dry collection cups and conditioned with Fluon or left untreated. Experiment 3 compared the number of cerambycid beetles captured in panel traps that were freshly treated with Fluon to untreated traps, and to traps treated with Fluon 1 and 2 yr before.

Materials and Methods

Site and Lure Description. The experiments were conducted at the Kellogg Experimental Forest (Kalamazoo County, MI), a Michigan State University research forest composed of 716 ha of mixed hardwood and conifer forests. Traps were positioned on the edge of a mixed hardwood stand where the dominant tree species were *Liriodendron tulipifera* L., *Quercus rubra* L., and *Carya cordiformis* (Wangenheim) K. Koch. The experiments were conducted from 20 May 2011–15 June 2011. The weather during this period consisted of 9 d with measurable rain and a total rainfall of 10.7 cm, an average ± SD maximum daily air temperature of 25.6 ± 5.9°C, and an average ± SD maximum daily wind speed of 29.9 ± 9.8 kph (http://www.agweather.geo.msu.edu/mawn/). Traps were placed in blocks along a transect ≈160–200 m in length at the edge of the stand. Traps were separated by ≥10 m and treatments were randomized within blocks. Blocks were separated by ≈10–15 m. Different experiments were separated by 0.5–1 km.

Lures were identical across experiments, and changed to attract to the most common species of cerambycids that were active at that time of year. Initially, traps for all three experiments were baited with 1 ml of citral solution (a 1:1 mixture of neral and geranial; diluted to 5% in ethanol; Sigma-Aldrich Co., St. Louis, MO), an attractant for *Megacyllene caryae* (Gahan) (Lacey et al. 2008; E.E.G., unpublished data). *M. caryae* was detected in the area during a preliminary survey; therefore, citral was chosen as the lure between 20 May 2011 and 2 June 2011, the peak activity period of *M. caryae.* Citral lures consisted of clear polyethylene sachets ("Zipper" press-seal bags Cat. No. 01-816-1A; 5.1 × 7.6 cm, 0.05-mm wall thickness, Fisher, Pittsburg, PA) to which the pheromone was added. The citral lures had a release rate of 1.39 mg ± 0.89/d (average ± SD) determined gravimetrically in the field during the course of the experiment. On 2 June 2011, lures for all traps in all experiments were replaced with the racemic pheromone blend of 3R-hydroxyhexan-2-one (3R*), synthesized as described in Millar et al. (2009) because the activity period of *M. caryae* was coming to an end. In screening trials, several species of Cerambycidae were attracted to mixtures of these stereoisomers (Hanks et al. 2007). Lures containing 3R* were constructed in the same manner as the citral lures, with 1 ml of 3R* solution (diluted to 5% in ethanol) added to polyethylene sachets. The 3R* lures had a release rate of 4.4 mg ± 1.6/d (average ± SD) determined gravimetrically in the field during the time they were deployed from 2 to 15 June 2011. Lures were replaced weekly.

Experiment 1: The Effect of Fluon on Lindgren Funnel Traps Fitted With Either Wet or Dry Collection Cups. Experiment 1 tested the effect of conditioning 12-unit Lindgren funnel traps (Contech Enterprises, Inc., Delta, British Columbia) with Fluon on the number of cerambycids captured in traps fitted with either wet or dry collection cups. The experiment was conducted from 20 May 2011 to 15 June 2011 and consisted of four blocks each containing four treatments: 1) Fluon-treated funnel trap with wet collection cup, 2) Fluon-treated funnel trap with dry collection cup, 3) untreated funnel trap with wet collection cup, and 4) untreated funnel trap with dry collection cup. We applied Fluon to the funnel traps by dipping the entire trap into a bucket of Fluon until the surface was thoroughly coated. Wet collection cups contained a saturated saline solution and 0.1% dish detergent (Meijer Corporation, Grand Rapids, MI). Dry collection cups were left empty and were fitted with a screen on the bottom to drain precipitation. Traps were suspended from L-shaped rebar poles (1.5 m high) with the bottom of the trap ≈0.5 m above ground. Trap contents were emptied six times during the study, every 3–5 d at which time the position of the traps was rotated within each block to control for location effects.

Experiment 2: The Effect of Fluon on Panel Traps Fitted With Either Wet or Dry Collection Cups. Experiment 2 tested the effect of conditioning cross-vane panel traps (Contech Enterprises, Inc.) with Fluon on the number of cerambycid beetles captured in either wet or dry traps. The experiment was conducted from 27 May 2011 to 15 June 2011 and was identical to Experiment 1 except we used panel traps instead of funnel traps. Trap contents were emptied four times during the study, every 3–5 d at which time the position of the traps was rotated within each block to control for location effect.

Experiment 3: The Effect of Fluon Over Time. Experiment 3 tested the efficacy of Fluon on traps after use over multiple years. The experiment was conducted from 24 May 2011 to 15 June 2011. We used identical cross-vane panel traps that were left untreated, freshly treated with Fluon in 2011, treated the previous year in 2010 (1-yr treated) (AlphaScents, Portland, OR) or treated with Fluon in 2009 (2-yr treated) (APTIV, Portland, OR). All traps were made of the same materials and were of same design and dimensions (black corrugated plastic, 1.2 m high × 0.3 m wide) and all traps were fitted with a wet collection cup containing saline solution as described in experiment 1. There were five blocks each containing four treatments: 1) untreated trap, 2) freshly treated trap, 3) 1-yr treated trap, and 4) 2-yr treated trap. Fluon was originally applied to traps using cotton pads (treatment 4) but paint rollers were found to be more efficient and were used for treatments 2 and 3. Traps treated with Fluon in previous years were used throughout the field seasons, and then flattened, stacked, and stored when not in use. Fluon was not reapplied. Trap contents were emptied five times during the course of the experiment, every 3–5 d at which time the position of the traps was rotated within each block to control for location effect.

Statistical Analysis. The statistical analysis was the same for all three experiments. Data for all species of Cerambycidae were combined and included in the statistical analysis. To correct for non-normal distribution and heteroscedasticity, numbers of beetles per trap catch were transformed by $\text{Log}_{10}(x + 1)$ (Sokal and Rohlf 1995) and differences among trap treatments in the number of beetles captured per trap were tested using analysis of variance (ANOVA) (PROC ANOVA; SAS Institute 2001). The model included the main effects for date, block, and treatment. The position of each trap was rotated within the block every time the traps were emptied; therefore, each trap catch was an independent replicate and not a repeated measure. Means per trap treatment were compared using the Ryan-Einot-Gabriel-Welsh range test (REGWQ; SAS Institute 2001). To enhance the statistical power of the test, all traps from date and block combinations that contained fewer than 10 beetles were eliminated from analysis (N = eight replicates remaining for experiment 1; N = eight replicates remaining for experiment 2; $N = 14$ replicates remaining for experiment 3).

Results

Experiment 1: The Effect of Fluon on Lindgren Funnel Traps Fitted With Either Wet or Dry Collection Cups. We captured 214 beetles of 15 species of Cerambycidae in funnel traps during experiment 1. The most numerous species were members of the subfamily Cerambycinae: *Anelaphus villosus* (F.) (31%), *M. caryae* (19%), *Xylotrechus colonus* (F.) (17%), and *Cyrtophorous verrucosus* (Olivier) (15%). *M. caryae* was only captured when the traps were baited with citral and *X. colonus* was only captured when the traps were baited with the 3R* pheromone. Citral is a major component of the pheromone of *M. caryae* (Lacey et al. 2008) and 3R* is a major component of the pheromone of *X. colonus* (Lacey et al. 2009) and *C. verrucosus* (R. F. Mitchell, personal communication). *A. villosus* was captured in traps baited with both lures.

There were significant differences among treatment means in the number of cerambycid beetles captured in funnel traps (Fig. 1; $F_{(3,23)} = 18.08, P < 0.0001$), with the Fluon-treated funnel traps with wet collection cups capturing the greatest number of beetles. The Fluon-treated funnel traps with dry collection cups captured significantly more beetles than the untreated funnel traps with dry collection cups, which failed to capture and retain a single beetle. There were no differences between numbers of beetles captured with Fluon-treated funnel traps with dry collection cups versus untreated funnel traps with wet collection cups. Fluon-treated funnel traps with wet collection cups captured ≈6× more beetles than untreated funnel traps with wet collection cups (Fig. 1). Fluon-treated funnel traps with dry collection cups captured ≈2× more beetles than untreated funnel traps with dry collection cups. There was no significant difference among the block ($F_{(3,23)} = 0.64; P = 0.60$) and date effects ($F_{(2,23)} = 0.24; P = 0.79$).

Experiment 2: The Effect of Fluon on Panel Traps Fitted With Either Wet or Dry Collection Cups. We captured 182 beetles from 18 species of Cerambycidae in panel traps during experiment 2. The most numerous species were *X. colonus* (54%), *M. caryae* (12%), and *A. villosus* (12%). As observed in experiment 1, *M. caryae* and *X. colonus* were only captured when the traps were baited with citral or 3R*, respectively. *A. villosus* was captured in traps baited with 3R*. There were significant differences among treatment means in the number of cerambycid beetles captured in panel traps (Fig. 2; $F_{(3,22)} = 31.96, P < 0.0001$). Fluon-treated panel traps with wet collection cups captured ≈9× more beetles than untreated panel traps with wet collection cups (Fig. 2). Fluon-treated panel traps with dry collection cups captured ≈11× more beetles than dry untreated panel traps with dry collection cups (Fig. 2). There was no significant difference among the block ($F_{(3,22)} = 1.04; P = 0.39$) and date ($F_{(3,22)} = 2.58; P = 0.08$) means in the number of cerambycid beetles captured.

Experiment 3: The Effect of Fluon Over Time. We captured 368 beetles from 21 species of Cerambycidae in panel traps during experiment 3. The most numer-

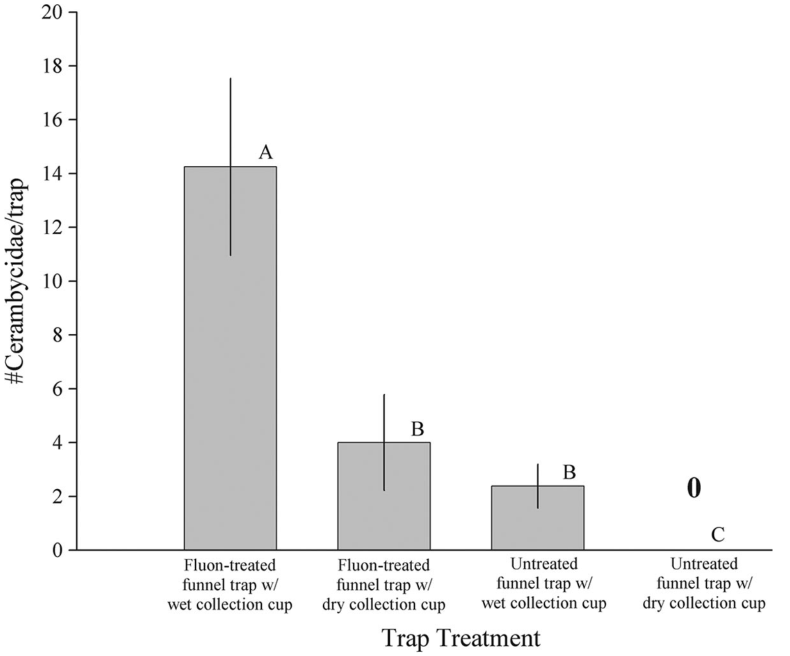

Fig. 1. Mean ± SEM number of Cerambycidae captured during experiment 1 in Fluon-treated or untreated Lindgren funnel traps fitted with either wet or dry collection cups and baited with lures loaded with synthetic pheromone. Bars designated with different letters were significantly different (REGWQ test $P < 0.05$).

ous species captured were *M. caryae* (42%) and *X. colonus* (34%). As in the previous two experiments the two dominant species were only captured when components of their pheromone were used in lures. There were significant differences among treatment means in the number of cerambycid beetles captured (Fig. 3;

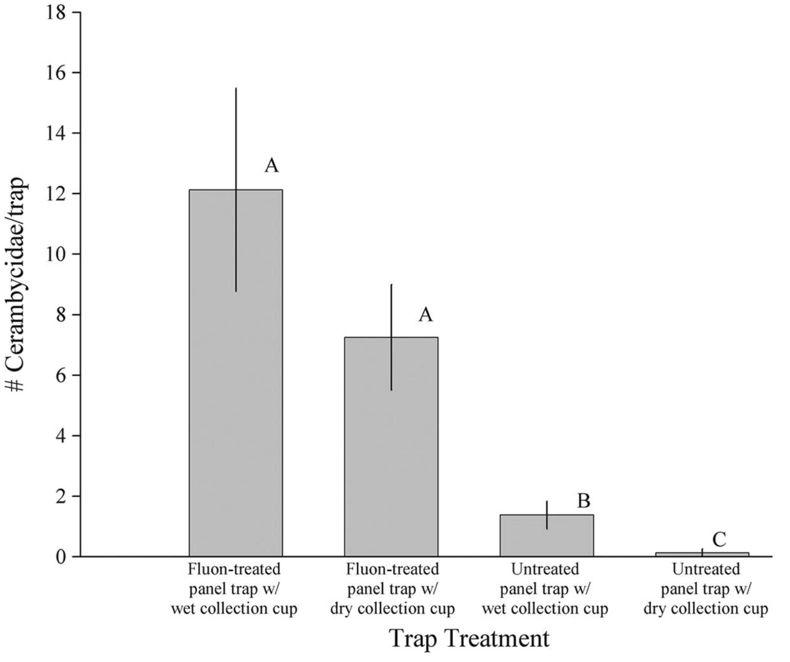

Fig. 2. Mean ± SEM number of Cerambycidae captured during experiment 2 in Fluon-treated or untreated panel traps fitted with either wet or dry collection cups and baited with lures loaded with synthetic pheromone. Bars designated with different letters were significantly different (REGWQ test $P < 0.05$).

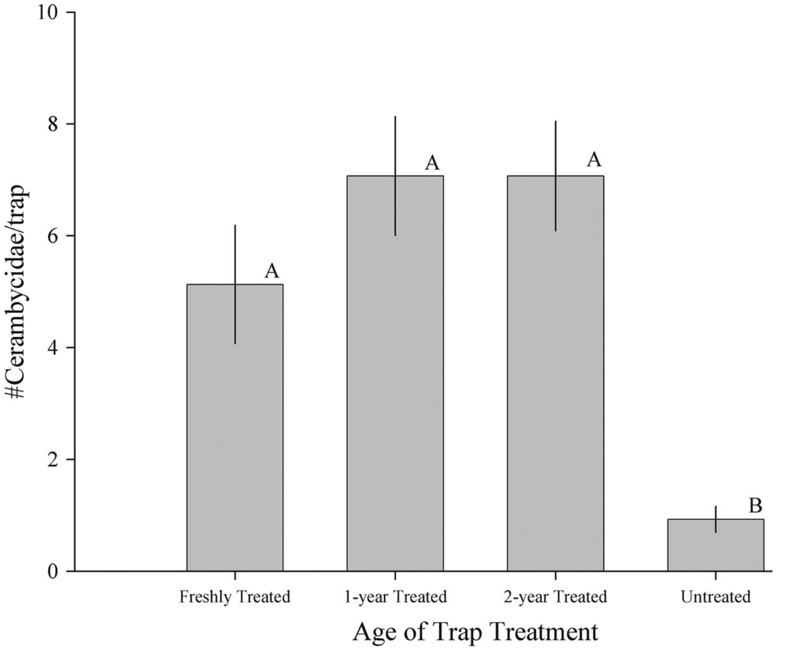

Fig. 3. Mean ± SEM number of Cerambycidae captured during experiment 3 in panel traps that were conditioned with Fluon 2 yr ago, 1 yr ago, freshly treated or left untreated, and baited with lures loaded with synthetic pheromone. Bars designated with different letters were significantly different (REGWQ test $P < 0.05$).

$F_{(3,48)} = 21.30$, $P < 0.0001$). There was no difference between the numbers of beetles captured in newly treated traps versus traps that had been treated 1 or 2 yr before. However, traps treated with Fluon, regardless of year treated, captured significantly more beetles than untreated traps. There was no significant difference among block means in the number of cerambycid beetles captured ($F_{(4,48)} = 1.11$; $P = 0.36$); however, there was a significant difference among date means ($F_{(4,48)} = 4.66$; $P = 0.003$). We captured significantly more beetles the week of 10 June 2011 ($n = 145$ total beetles) than the week of 2 June 2011 ($n = 52$ total beetles); however, the pattern of the treatment effects remained the same. Mean number of cerambycid beetles captured did not differ significantly among any other dates.

Discussion

Fluon-treated funnel traps with wet collection cups captured more beetles than untreated funnel traps with wet collection cups, suggesting that Fluon increases the number of beetles captured. Fluon-treated funnel traps with dry collection cups did not capture significantly more beetles than untreated funnel traps with wet collection cups, suggesting that beetles may escape after falling into the dry collection cup. This has been demonstrated in previous studies comparing wet versus dry trapping methods (Morewood et al. 2002, de Groot and Nott 2003, Sweeney et al. 2006). However, Fluon-treated funnel traps with dry collection cups did capture an average of four beetles per trap per collecting period whereas untreated funnel traps with dry collection cups failed to capture and retain a single beetle (Fig. 1). We conclude that untreated funnel traps fitted with a dry collection cup and no killing agent are not effective at capturing cerambycid beetles.

The results of experiment 2 support previous findings that Fluon increases the efficacy of panel traps for capturing cerambycids (Graham et al. 2010) and demonstrated that it is effective for both wet and dry traps. The Fluon-treated panel traps with either wet or dry collection cups captured significantly more beetles than untreated panel traps with either wet or dry collection cups. Similar to experiment 1, we conclude that untreated panel traps with a dry collection cup and no killing agent are not effective at capturing and retaining cerambycid beetles. However, Fluon-treated panel traps with dry collection cups are as effective at capturing and retaining cerambycid beetles as Fluon-treated panel traps with wet collection cups. Traps fitted with dry collection cups allow beetles to be captured alive and used for studies of the behavior and chemical ecology of cerambycid beetles.

Experiment 3 demonstrated that the effect of Fluon on capturing cerambycid beetles does not decline after use in one or two field seasons. There was no significant difference in the number of beetles captured in freshly treated panel traps compared with traps that had been used for 1 or 2 yr (Fig. 3). It is possible the effect of Fluon could diminish after further use in the field and long-term storage because Fluon can flake off the surface of the traps, but spot treatments of fresh Fluon should be sufficient to recover any lost efficiency. The application method did differ for the traps treated 2 yr prior compared with the freshly treated and 1 yr treated traps; however, the coverage looked similar for both methods, and the paint roller made for a faster and more efficient method.

The difference in the efficacy of Fluon on funnel traps compared with panel traps may be because of the type of plastic used for the traps. Lindgren funnel traps are made of a high-density polyethylene (Contech Enterprises, Inc.; J. Borden and B. Southin, personal communication), which does not bind well to surface treatments. The cross-vane panel traps are made of corrugated polypropylene (J. Borden and B. Southin, personal communication), which is more abrasive in texture than the very-smooth high-density polyethylene, providing a surface more suitable for binding. The Fluon did not adhere to the surface of the funnel traps as well as it did to the panel traps, and it easily flaked off during rain storms and while handling the traps. When the Fluon flaked, bare patches were exposed on the funnel, providing a surface from which beetles could alight and take flight.

Overall, traps treated with Fluon captured significantly more beetles than untreated traps, regardless of trap type or collection cup. The effect of Fluon is less dramatic on traps with a liquid killing agent because the beetles are unable to escape from trap collection cups once submerged in the liquid solution in wet collection cups. However, treatment of traps with Fluon does significantly increase the number of cerambycid beetles captured by preventing beetles from alighting on the surface and flying off rather than falling directly into the collection cup. Fluon-treated traps captured nine species that were not caught in untreated traps, which could influence the results of species composition studies. Our results indicate that a one-time treatment of Fluon on intercepts traps (with possible touch up in subsequent years), enhances the efficacy and sensitivity of traps deployed to detect exotic cerambycid species, or for monitoring threatened species at low population densities.

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